Genetic Research With Experimental Dairy Cattle at the Beltsville Agricultural Research Center

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GENETIC RESEARCH WITH EXPERIMENTAL DAIRY CATTLE AT THE BELTSVILLE AGRICULTURAL RESEARCH CENTER

By Robert H. Miller, research geneticist[1/]

This report summarizes genetic research with experimental dairy cattle during 1968-77 at Beltsville, Md. The period chosen is arbitrary, but research in which distinct genetic types of dairy cattle are created must cover a substantial period because of the long generation interval. Some theoretical or simulation work is included without use of collected data. Various cooperative endeavors are described, including projects in which Beltsville Agricultural Research Center (BARC) data were utilized by researchers at other facilities and projects in which the Genetics and Management Laboratory personnel participated, although some or all of the data may have originated from other sources, such as Dairy Herd Improvement (DHI).

CROSSBREEDING RESEARCH

Holstein-Brown Swiss-Ayrshire Crossing

In 1957, R. E. McDowell at BARC undertook an experiment to determine whether a cross with some combination of the Holstein, Brown Swiss, and Ayrshire breeds would be superior to the best of the pure breeds (Holstein). Most of the results were reported during 1968-77. This research was stimulated by the success of efforts with other species to capitalize on heterosis or "hybrid vigor."

Briefly, 40 heifer calves of each of the 3 breeds were purchased as a foundation herd. The 120 heifers came from 85 herds and 120 dams; they were sired by 105 bulls. The foundation constituted one of the most successful recorded attempts to obtain representative samples of the breeds in a crossbreeding experiment. This permitted some general conclusions about the results that would not otherwise have been possible. Comparisons were made among the three pure breeds, all the possible two- and three-breed crosses, and the backcrosses of H X (S X (A X H)) and H X (A X (S X H)).[2/]

Production and feed intake, health and viability, reproductive performance, growth rate, and economic aspects were reported (22-26).[3/] All breed groups

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[2/] H = Holstein, S = Brown Swiss, A = Ayrshire.

[3/] Underlined numbers in parentheses refer to Literature Cited at the end of this report.

were inferior to purebred Holsteins in milk yield; the best single crosses (S X H and A X H) produced about 4 percent less than Holsteins. However, five crossbred groups were more efficient in feed conversion than Holsteins, whereas A X H crosses, Brown Swiss, and Ayrshires were less so.

Although differences in frequency of mastitis infections were generally not significant, purebreds generally had fewer infections than crosses during first lactation. Brown Swiss required fewest treatments for diseases and injuries, but some types of crosses had fewer treatments than the pure Holsteins and Ayrshires. When total veterinary costs from birth to end of first lactation were calculated, crossbreds as a group had no general advantage, but the specific crosses A X H, H X (A X S), and S X H were comparable to pure Holsteins. A X H had the least veterinary cost.

The purebreds as a group had fewest calves born dead, but the two-breed crosses subsequently had superior viability later in life as compared to purebreds and three-breed crosses. Brown Swiss had the highest death losses of calves, whereas Ayrshires had less than average calfhood deaths. Crosses generally were more viable during calfhood than were purebreds.

Crosses as a group were comparable to purebreds in days from first service to conception and proportion pregnant at 95 days after calving. However, crosses were superior to purebreds in the proportion pregnant by 145 days after calving. Thus, fewer crosses were nonbreeders, although fertile crosses bred back no faster than fertile purebred cows. Holsteins showed the earliest conception of fertile cows but had a higher proportion of nonbreeders. For proportion conceiving by 145 days, the best three breed groups were the single crosses with Holsteins (S X H, H X S, A X H). Thus, heterosis in female reproduction appeared to be manifested in the proportion of cows that ultimately conceived but not in the rapidity of conception of fertile cows. McDowell et al. (26) concluded that the reproductive superiority of crossbred Holsteins partially offsets their lower milk yield.

There was negative heterosis, with crossbreds poorest, for birth weight and weight gain during lactation, but heterosis in heifer growth ranged from 2 to 4 percent, which was not sufficient for much reduction in average age at first calving.

McDowell and McDaniel (24) expressed the differences among breed groups in economic terms. Calculations of income over feed cost (IOFC) showed that Holstein crosses as a group exceeded pure Holsteins. The highest ranking breed group of all in IOFC was S X (A X H), which exceeded income of pure Holsteins by 5 percent. When costs of health care, deaths, and maintenance of dry cows were deducted from IOFC, the crosses A X H, S X H, and H X (A X S) were comparable to or slightly superior to Holsteins in net returns.

In assessing the implications of their work, McDowell and McDaniel (24) reached the following conclusion: "In spite of these difficulties, the results show clearly that the total advantage of any one breed group cannot be predicted simply from its comparative performance for any individual trait, and they emphasize that the most profitable dairy animal under one set of circumstances may not necessarily be superior in others." The authors further concluded that " . . . crossbreds may equal or surpass purebred cows in many

aspects of performance." In other words, to assess the overall value and usefulness of alternative types of cattle, one must evaluate their total performance and not solely one economic trait.

Cooperative Crossbreeding Research

The previous experiment by McDowell et al. (22-26) was a contributing part of S-49, the southern regional dairy cattle breeding project. As such, the data were used in several regional studies. In a cooperative report, reproductive performance of all crossbreds at four research stations was analyzed (28). No significant trend favored any of the four breeds involved. Crossbred matings required about the same number of services per conception as purebred matings. However, considering several traits, crossbred reproductive performance was slightly superior to that of the four pure breeds.

In a study of growth of purebreds and crossbreds, BARC data were utilized (27). Heterosis estimated from two-breed crossing results was significant in several growth traits relating to ages 6-36 months. Heterosis in three-breed cross combinations was smaller. No evidence of maternal effects on growth was found.

In another S-49 report (59), BARC data were used to measure the importance of additive, heterotic, and maternal effects on milk yield. Estimates of percent heterosis ranged from 3.4 for Ayrshire X Swiss to 10.6 for Ayrshire X Holstein. The overall percent heterosis was 7.5 for two-breed crosses, 5.0 for three-breed crosses, and 2.1 for five-eighths crosses. Reciprocal effects were important in Ayrshire X Holstein crosses. Holstein dams were superior in their maternal effects.

In a related cooperative study with other BARC workers (7), the foundation cows of the three breeds were compared for different traits using some of McDowell's data. Comparative gross feed efficiencies for Holsteins, Ayrshires, and Brown Swiss were 0.61, 0.60, and 0.54, respectively. When body weight was held constant, Holsteins were significantly more efficient than Ayrshires. Corresponding to other results, regressions of feed efficiency on measures of body size were negative for all breeds.

Simmental X Holstein Crossing

In the early 1970's, the U.S. beef cattle industry underwent a painful reassessment of its selection goals. Many in the industry concluded that the former goal of creating a small, blocky animal that fattened rapidly under feedlot conditions was not satisfactory. This may have been due partly to changes in consumer preferences relating to fat composition of animal products. In revising goals of genetic improvement, there was a large-scale effort to introduce and test "exotic" European breeds as a means of speeding genetic changes. One of the breeds introduced was the Simmental, a dual-purpose animal bred in Germany, Austria, and Switzerland.

Owing to restrictions against importing live animals, the primary mode of introducing Simmentals was "grading-up" to approach pure breed status by backcross mating successive generations of crossbred females to Simmental bulls through artificial insemination. Through this service to Simmental bulls, the lower strata of dairy herds might provide a source of crossbred animals if the milking attributes of the female crosses were not radically unprofitable.

With this in mind, K. E. Gregory of the U.S. Meat Animal Research Center (MARC) at Clay Center, Nebr., and R. D. Plowman of BARC decided that a crossbreeding experiment was necessary to assess the milking characteristics of single-cross Simmental X Holstein females as well as the meat production qualities of crossbred males. The matings and female performance measurements were made at Beltsville. Crossbred and contemporary purebred males were shipped to Clay Center for growth and feedlot performance assessment. Because of other work and fewer cows during the 1960's, only a few crossbred matings were possible. An effort was made to secure semen from all Simmental bulls available in the United States at the time. A total of 24 crossbred females were evaluated through first lactation and were compared to 49 pure Holstein heifers that were contemporary in the concurrent selection experiment.

Body weights of crosses and Holsteins were similar at birth and calving. Crosses tended to gain more weight during lactation than Holsteins and completed their first lactation 21.8 kg heavier (9). Crossbred heifers were shorter at withers and smaller in heart girth at first calving but were similar to Holsteins when the first lactation ended. Health differences were small, but Holsteins had more mastitis infections and consequently higher treatment costs. Crossbreds had more treatments for reproduction problems, especially retained placentas and difficult births. Crossbred heifers displayed first estrus about 3 weeks later than Holsteins, suggesting that Holsteins reach maturity earlier than Simmentals. Crossbreds required almost one less service per conception than purebred Holsteins, perhaps reflecting heterosis in reproductive performance.

Each group averaged about 24 months in age at first calving. Crosses reached the dry-off milk level about 1 month earlier than Holsteins and produced 2,321 kg less milk, 70 kg less fat, 190 kg less solids not fat, and 70 kg less protein. As expected, fat composition of milk from crosses was higher than that from Holsteins (4.0 vs. 3.7 percent).

Results of the feedlot comparison at MARC (3) show that at a constant slaughter age crossbred steers significantly exceeded contemporary Holstein steers in final weight (555 vs. 525 kg), carcass weight (302 vs. 272 kg), and estimated retail product from primal cuts (148 vs. 132 kg) and from total carcass (210 vs. 188 kg). Likewise, the Simmental crosses were superior in conformation grade and rib-eye area. These results perhaps reflect the selection history of the dual-purpose Simmental breed for meat quality.

It was concluded that production of Simmental crosses in dairy herds would not be profitable unless a worthwhile market in the beef industry were available for both the male and female offspring. Crossbred females should not be retained for dairy use, and hence only single crosses could be supplied by dairy herds. These would no longer be in much demand once the breed formation process was well along.

MATING SYSTEMS

In 1957, a project was undertaken by R. D. Plowman with broader objectives than the experiment by McDowell et al. (22-26). The goal was to compare three basic mating alternatives available to dairymen. These were (1) mating their herd to the best artificial insemination (AI) sires available within their own breed; (2) mild inbreeding with selection, utilizing bulls born within their own herd; and (3) crossbreeding with semen from bulls of several breeds available in AI. When the project began, the success of selection and the use of AI was still somewhat questionable, use of crossbreeding was still debatable, and many breeders believed that they should pursue their own internal breeding programs.

Although crossbreeding was an integral part of the project, estimating the degree of heterosis in various aspects of performance was not an objective. Hence, only a base herd of Holstein females constituted the foundation cows of the project. The herd was randomly divided into three units--one for outcross matings, one for a mild inbreeding program, and one for crossbreeding.

The mild inbreeding phase was carried out by making pedigree selection of young bulls born within the mild inbreeding line itself and loaning them to AI units, State and Federal institutional herds, and private dairymen. Progeny test information thus obtained was the basis for selecting the bulls that were used to propagate the mild inbreeding line.

In the crossbreeding phase, both general and specific combining ability variation was utilized to increase performance. That is, the bulls used for crossing were selected on the basis of their intrabreed progeny test evaluations. Higher performance should be generated by this method compared to a random choice of bulls within the breeds used to form the crosses.

The availability and accuracy of progeny test evaluations during the project presented a serious barrier to its success. Analysis of results (8, 14-16, 47, 53, 56) indicated a positive trend in milk yield of outcross cow generations. Performance of the various mildly inbred generations was erratic. Crossbred groups differed significantly; the backcross H X (S X (A X H)) was the highest yielding group, apparently owing to both additive and heterotic effects.

Mating systems differed significantly for first lactation milk, solids not fat (SNF), percent SNF, and percent protein. The outcross group was superior for all yield traits; the crossbreds generally had highest milk composition; and the mild inbreds were well below outcrosses in milk (5,951 vs. 6,226 kg in the all-lactation summary).

There were breed group differences in growth rates of heifers. Mild inbreds were consistently lighter than outcrosses at birth and throughout life. Crossbreds were lighter than outcross Holsteins early in life but grew faster and reached comparable mature weights. The reduced size of mild inbreds could not be ascribed to correlated selection response nor in totality to inbreeding depression. Inbreeding in this group averaged only about 3 percent.

When the estimated breeding values (PD 74)[4/] of the bulls used were considered, about two-thirds of the difference between outcrosses and linebreds was accounted for, suggesting that nonadditive genetic effects may have had some role.

Although separation of additive and nonadditive genetic effects cannot be obtained, comparison of A X H, S X H, and first-generation outcrosses gives an estimate of the impact of Ayrshire, Brown Swiss, and Holstein sires when mated to similar groups of Holstein cows. Compared to first-generation outcrosses, Ayrshire- and Brown Swiss-sired cows produced, respectively, 617 and 459 kg less milk, 52 and 15 kg less SNF, and 17 and 1 kg less protein; i.e., Brown Swiss sires had a less detrimental impact on milk yield than Ayrshire bulls.

Analysis of milking rates and times disclosed a genotype X environment interaction. Interaction of mating system with three different milking systems in the project was significant for both machine and total milking time.

When other traits such as feed intake, feed efficiency, milking rate and time, and growth rate are considered, the results do not displace outcross Holsteins as the superior mating system. However, milk yield of the H X (S X (A X H)) backcross was superior to that of outcross Holsteins (6,270 vs. 6,226 kg). This result shows that possibly specific crosses can be found that rival Holsteins, even though crosses generally are inferior, particularly if both additive and nonadditive variances are utilized, as in this project.

These results show that dairymen should participate fully in population improvement programs through artificial insemination rather than devising their own internal herd mating system. The only situation justifying a separate breeding policy would be when selection goals are perceived to be markedly different from those pursued in the population as a whole. Even then, the subpopulation should be large enough to avoid inbreeding problems.

The crossbreeding results of R. D. Plowman's project, in conjunction with those of McDowell et al. (22-26), help to identify unique crosses that perform comparably to purebred Holsteins. These findings may be useful if revised breeding procedures are required to overcome selection limits or decreased overall genetic fitness due to unfavorable correlated responses. In particular, the results suggest that there may be merit in a crossbreeding system that also takes advantage of additive breeding value within separate breeds. An experiment to further test this possibility is underway at Jeanerette, La.

FEED EFFICIENCY

During the mating systems project daily feed intake of lactating cows was recorded. This aspect of performance was a long-standing interest of N. W. Hooven, Jr., at BARC and R. D. Plowman. There was very little information to support the supposition that genetic gains in milk yield produced improved feed efficiency, and certainly there was no way to quantitively project

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[4/] Predicted differences with 1974 base.

expected correlated genetic responses in gross feed efficiency or increased feed consumption that would result from selection for milk. Another objective was to determine how body size might be used in selection where improved feed efficiency is part of the selection goal. Thus, as an adjunct to the mating systems project, there were several studies pertaining to these relationships (10, 11, 13, 36-39, 43).

Heritability of feed efficiency (fat-corrected-milk yield divided by estimated net energy consumed) was about 80 percent of that of milk yield. Heritability of feed intake was about 66-2/3 percent of that of milk yield. The key results were that the estimated genetic correlation between milk yield and feed efficiency was 0.86 and the corresponding relation between milk and feed intake was 0.76. These results permitted for the first time the projection of responses from different selection criteria, provided assumptions were made regarding relative selection intensities of alternatives.

Expected correlated responses achieved in feed efficiency as a result of milk selection were projected to be 97 percent as large as those achieved if all selection decisions were based solely on feed efficiency. This suggests that direct selection for efficiency would not be needed even if required data were available.

However, when changes in feed consumption resulting from alternative selection criteria are projected, the situation is not as satisfactory. When changes in consumption resulting from milk selection are compared with those expected from selection for feed efficiency, feed consumption increases would be 95 percent greater from milk selection. This arises largely from the high negative genetic correlation between efficiency and body weight. That is, selection for efficiency decreases the maintenance requirement, whereas milk selection would have relatively little impact on absolute maintenance needs but would only reduce maintenance feed as a proportion of total intake.

The primary drawback of making gross feed efficiency an overt selection objective, aside from the question of available population data, is the decreased rate of improvement in milk yield that would result. Formulation of optimum selection criteria under different economic conditions still remains to be worked out. However, Dickerson[5/] used these results to infer that negative selection emphasis on body weight would be desirable from the standpoint of controlling increased feed consumption.

This work at Beltsville was coordinated with feeding system-sire interaction experiments conducted at the U.S. Department of Agriculture experiment stations at Logan, Utah, and Lewisburg, Tenn.

Other subsidiary results from this work are as follows: (1) Feed intake and efficiency measurements of individual cows are most accurately obtained during midlactation and have part-whole correlations of 0.9 to 1.0 (11, 12). (2) There are striking changes in the correlation between body weight and other

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5/ Dickerson, Gordon. Efficiency of animal production-molding the biological components. Jour. Anim. Sci. 30: 849-859. 1970.

traits depending on the stage of lactation at which weights are obtained (43). For example, the correlation between lactation milk yield and body weight 1-30 days after first calving was 0.17, whereas the corresponding correlation for 271-300 day weights was -0.17. This finding suggests that variations in the time at which weights are measured account for some of the confusion in the literature regarding relationships with body weight. (3) Studies of the relation between change in body weight during lactation and milk yield performance suggest that weight change, or alternatively perhaps, changes in heart girth, during lactation may provide a means of adjusting yields for intraherd environmental fluctuations, such as those in feeding (38, 39).

OTHER RESEARCH DURING MATING SYSTEMS PROJECT

Several other lines of research were pursued in relation to the mating systems project, but their objectives were less related to systems of mating or feed efficiency.

Measuring Economic Efficiency

An investigation was carried out to evaluate alternative measures of the efficiency of milk production, with the ultimate goal of a selection criterion that more fully reflects the profitability of the production process (40). When yield, feed efficiency, income over feed cost, and feed cost per unit milk output were evaluated using various combinations of the values of milk, grain input, and forage input, income over feed cost appeared preferable as a measure for discriminating among cows, since it was less sensitive to environmental fluctuations. Other conclusions were (1) days open should be reduced to the minimum needed for an adequate length of the subsequent dry period; (2) body weights at first calving in excess of 550 kg were unprofitable, since increased yield did not compensate for increased maintenance cost; and (3) current fat differentials used in milk pricing in the industry do not favor increasing fat composition.

Pearson (51, 52) also considered the problem of choosing a measure for economic comparisons. He pointed out that such factors as growth rate and costs of AI services and health care present special problems in evaluation because of their high degree of variability, even within herds. Another report by Pearson (50) pertained to the "diminishing returns" principle in milk production, i.e., whether "profit" per unit output is lower at high levels of yield than at intermediate levels.

Milking Rates

Rate of milking and time required for milking are often economically important traits that may justify inclusion in selection decisions. During the mating systems project, data were obtained to evaluate genetic and nongenetic effects on these variables related to milking labor requirements. Results (34, 48) indicated that peak flow rate is a distinct characteristic of individual cows and would respond readily to selection pressure. However, milking time was determined more by milking management factors. Since peak flow rate has a

high genetic correlation (0.7) with milk yield, adequate improvement is made through milk selection; on the other hand, the results indicated that total time required to milk individual cows can be expected to increase moderately, since there was a positive genetic correlation between milking time and milk yield (0.5). Such changes can be offset in part by altering the organization of milking, such as increasing the number of units per milker.

Estimating Total From Part Lactation Yields

In deciding how to handle incomplete lactations of animals within the BARC herd, it was concluded that the current gross ratio method was not very satisfactory. Several alternative methods were examined, including the ratio method, various regression methods, and utilizing some function of the available tests to estimate the unknown remainder of lactation (first suggested by Miller et al. (46)). Both BARC herd and DHI data were used.

For the first report of this work (42), a simplified version of regression was found to be superior to ratio projections, especially during the first 90 days of lactation. In the second report (46), a new method of estimating the remainder of lactation from the last available test was comparable in precision to multiple regression projections while at the same time being much easier to implement. Since this work was published, the new method has appeared extensively in the Dutch, French, and Scandinavian literature.

Comparison of Holsteins and Jerseys

Data on the comparison of Jerseys and Holsteins under contemporary conditions are so sparse that some Beltsville data were studied to gain some idea about relative production efficiency (12). Holsteins were highest in fat-corrected-milk yield and feed consumption, but Jerseys were more efficient in feed utilization ($P < 0.05$), where efficiency was fat-corrected-milk yield during days 100-200 of lactation divided by estimated net energy consumed during the same period. Both breeds showed positive regressions on years for all traits except fat percentage of Jerseys.

In another report (29), growth measurements of Holsteins and Jerseys were compared. The results showed that Jerseys matured about 2 percent faster than Holsteins. Anatomical statistics were reported that should be useful in designing stalls for milking parlors and barns. Analysis of inbreeding effects on growth confirmed the usual finding that rate of growth is retarded by inbreeding but mature size is unaffected.

COMPARISON OF TWO SELECTION CRITERIA

At the conclusion of the mating systems work under R. D. Plowman's direction, a selection experiment was undertaken by J. W. Smith at BARC. The primary objective was to determine whether intense selection for early milk yield was a more profitable policy than combined selection for milk, percent fat, longevity of a bull's progeny, and udder conformation. Some Canadian research has indicated a very distinct diminishing net return for high expected

breeding value levels. Since a wide spectrum of individual cow characteristics and cost-related variables was to be measured, an accurate judgment of returns above costs can be determined. Although averages from the BARC herd are not directly applicable, relationships between the various inputs and outputs should be more widely useful. In conjunction with this, formulation of selection criteria as alternatives to milk yield was to be pursued.

The experiment utilized the design proposed by Hickman and Freeman of Iowa State University to allow intraline estimates of genetic change. This design capitalized, through frozen semen, on using the same bull at widely varying periods to disentangle genetic and environmental changes.

Preliminary results are only now becoming available. Based on 160 first lactations, the milk yield group exceeded the multiple trait group by 550 kg (mature-equivalent basis). This compares to an expected difference of about 400 kg based on average predicted differences (PD's) of the sires that were used. Although there is strong evidence in the literature for a multiplicative effect of environment on expression of genetic potential, the relatively low herd average at BARC would not have led one to expect performance to exceed estimated breeding value. It will soon be possible to determine whether adding later lactations causes this difference to be reduced (the sires for the milk line were selected solely on a first lactation progeny test).

Of course, the primary objective related not to the difference expected in milk but to the comparison of net returns between the two groups. Although it is much too early to make any judgment about this, some results are becoming available. Milk-yield heifers consumed on an average 440 kg more feed than multiple-trait heifers. The yield heifers also had a shorter average distance from ground to low point of the udder, suggesting the possibility of greater risk of udder injury. Thus far, there are no significant differences in milking rate, milking time, body weight, or linear body measurements. No information is available yet on differential health and reproduction costs.

Type and Longevity

In pursuit of establishing selection criteria, a study was undertaken to determine whether various segments of type classification summaries of sire progeny groups were related to the evaluations of the sires for milk and fat and to the percentage of incomplete first lactations reported in DHI herds (41). Justification for attention to conformation traits often includes the claim that longevity is superior for animals that meet the breed ideals for conformation. Only udder type traits were significantly related to milk transmitting ability, but these relations were such that inferior udder conformation was associated with superior transmitting ability. Elements of progeny type classification appeared to be essentially unrelated to percentage of incomplete first lactations after the effect of the sire's estimated breeding value for milk was removed.

The Role of Economics in Selection

Since economic considerations have an important role in the formulation of optimum selection criteria, the literature was extensively reviewed regarding the application of economic principles to the evaluation of alternative selection systems. The review (31) was published in 1977.

Previous research that failed to apply economic criteria often erred by advocating selection alternatives that maximized genetic gain per unit time. Such options are not necessarily the most profitable alternatives, especially when future gains are discounted to present value. Differences in selection goals and practices between the United States and Europe were discussed. Only if international selection goals become more uniform will exchanges of semen be worthwhile for improvement programs.

Variation in Fat Percentage

As part of the effort to answer some of the questions about AM-PM production recording systems, a study was conducted by B. T. McDaniel, then with the BARC DHI group. Fat composition was determined for 13,384 individual samples over 88 consecutive days. At this time little was known about the relative importance of various sources of variation in fat percentage determinations. Results of the study (54) were as follows: (1) The effects of stage of lactation were much greater on milk yield than on fat composition, (2) random variation associated with day-to-day fluctuations of the same cow at the same stage of lactation was much more important for percent fat than for milk, and (3) the within cow-day variance of percent fat was much less inflated by unequal milking interval than was that for milk yield. The implication of these results is that procedures for predicting lactation values in an AM-PM testing plan must be different for milk yield and fat composition.

AM-PM Recording

BARC data consisting of individual milking weights for 536 lactations were used in a cooperative study by DHI personnel of alternative milk recording systems (5) and also in a later Wisconsin study. Estimated lactation yields were computed for the various alternatives and compared to actual. Conclusions were as follows: (1) Biases in both DHI and the alternative method were reduced to a tolerable level by adjusting individual milking weights to a 12-hour milking interval basis and (2) adjustment for a milking interval would be desirable regardless of the testing method used.

Relationship Between Predicted Difference Milk and Income Over Feed Cost

One of the historical problems in convincing dairymen to utilize sire evaluations expressed in terms of milk yield and age-adjusted milk yield was that their relationship to profit-related functions had not been clearly demonstrated. An early attempt to clarify this relationship was made by DHI personnel, utilizing the purebred segment of the data collected in McDowell's

crossbreeding project (20, 21). Since the design of McDowell's experiment included forming separate foundation female lines of each of the three breeds, and since an attempt was made to have as many sires as possible represented in the foundation cows, it was possible to obtain accurate estimates of the regression of daughter performance traits (measured only in the BARC herd) on predicted difference (PD) milk (DHI population estimate). Based on the prices assumed for inputs and outputs at that time, it was estimated that there was a linear increase of $7.08 in income over feed cost of a random daughter for each 100 kg increase in a bull's PD milk evaluation. These results have been the basis of successful subsequent promotional efforts to encourage the use of high PD bulls (4, 6).

Studies of Mastitis Incidence

Since mastitis is one of the nonyield traits with greatest economic impact, efforts have been made to define its possible role in selection decisions. The first problem is to examine the many ways in which mastitis incidence or mastitis resistance can be expressed. As a secondary problem, factors that affect each alternative measure must be assessed. Utilizing data on the frequency of antibiotic treatments of the disease in the BARC herd and in the USDA herd at Lewisburg, Tenn., these problems were examined for alternatives relating to actual treatment with antibiotics as opposed to cell count or bacteriological tests.

In three such studies (44, 45, 49), the results were as follows: (1) More treatments for infection are made in rear quarters than in front quarters; (2) resistance to infection is more fully manifested in later lactations compared with first lactations; (3) season-of-calving effects on frequency of treatment are not large; (4) total number of treatments during a lactation is preferable compared to all-or-none traits of infected/noninfected; (5) accounting for stage of lactation at which treatment occurs may increase the sensitivity of measurement; and (6) higher levels of milk yield are associated with increased frequency of treatment.

A subsequent study was made of a second basic way to measure mastitis by estimated cell count as reflected in the Wisconsin Mastitis Test or WMT (2). The correspondence of the screening tests to actual infections was determined by carrying out bacteriological tests for presence of organisms in quarter milk samples. Cows with pathogens in at least one quarter had average WMT scores, adjusted for parity and stage, of 5.5 units higher than cows with no organisms. The presence of the more highly pathogenic organisms was associated with higher WMT scores than the presence of *Corynebacterium bovis* or *Staphylococcus epidermidis*. The best WMT critical point for classifying cows as infected or not infected seemed to be between 3.5 and 5.5. Further accuracy can be gained by considering the age of the cow. This problem is being pursued still further through a BARC cooperative project at the University of Wisconsin.

Recording Reproduction and Health Data

Part of the difficulty in assembling information about frequencies of health treatments and reproductive performance relates to classifying health problems and to developing workable computerized systems for recording reproductive events. BARC workers evaluated a herd reproduction system developed at N.C. State University but concluded it was inadequate. Miller et al. (35) developed a computerized system to capture these kinds of events. Being primarily designed for research purposes, the system may be more detailed than required for field use, but it is being adapted for use at the DHI Processing Center, Provo, Utah.

Data Handling Systems

R. E. Pearson at BARC reported on systems for capturing and organizing data on groups of cattle used for research. He discussed both concepts to be considered in planning a retrieval system and described the actual data handling systems that have been developed in the Beltsville Genetics and Management Laboratory.

Genetic Differences in Nutritional Requirements

Reflecting past involvement in BARC research on genetic-nutrition interaction and related topics, a request was received from the Chemical Rubber Company to prepare a review of knowledge on genetic variation in nutritional requirements of dairy cattle to be published in its "Handbook of Nutrition and Food" (32). Such a review inevitably underscores the paucity of knowledge in this area. Most is known about differences relating to energy requirements, but information diminishes rapidly when one studies such dietary elements as minerals and vitamins. There is evidence that Zebus possess a lower maintenance requirement per unit of body mass compared with European breeds and that Zebus likewise may require less of certain trace elements such as zinc.

Interactions of genotype by caloric density of diet have not been large, but there is a suggestion that genetic differences gradually develop between cattle subjected to prolonged selection under diets differing greatly in grain to forage ratios. If various national cattle strains are subjected to widely differing nutritional regimes, and if exchanges of genes are restricted, those small interactions suggest that an additional source of genetic variation will be built up.

Developing a review of this body of knowledge underscores the need for multidisciplinary research involving both genetically distinct cattle types and treatments designed to establish nutritional needs. Unfortunately there is little indication that this need is understood or that required teamwork is likely to take place.

Conservation of Cattle Germ Plasm

Even though genetic improvement of dairy or dual-purpose cattle tends more and more to concentrate on intrabreed selection, existing sources of genetic variability should be preserved for future uses that may not be foreseeable at present. To draw attention to the losses that are likely to occur without conservation, Miller (33) reported on the future contingencies that may require alternative sources of genetic material and made suggestions for organizing a conservation program. He also pointed out that cattle species are uniquely desirable in having a long-term conservation mechanism for genetic material.

Cow Evaluation in North America

In 1977, Pearson and Miller (55) presented a review of cow evaluation programs to the European Association of Animal Production. It was based on past work with cow culling or selection systems. They emphasized the two basic purposes of evaluation--for genetic selection decisions, such as choice of bull dams, and for herd culling decisions. In the former, the objective is to estimate genetic ability, whereas in the latter it is to estimate future producing ability, which includes contributions of permanent environmental effects.

Review of Regional Project S-49

White et al. (60) summarized the research achievements of the southern regional dairy cattle breeding project, S-49. This covered crossbreeding results from BARC, previously discussed, as well as those from other contributing stations, including the former USDA experiment station at Jeanerette, La. Other noteworthy achievements documented were the North Carolina pilot scheme, which demonstrated the success of selection based on progeny test, even in a relatively small population, and the regional effort to characterize the genetic parameters of milk composition traits.

OTHER COOPERATIVE RESEARCH

Blood Transferrins

R. H. Miller cooperated with C. A. Kiddy of the BARC Reproduction Laboratory in a study of the relationship of the iron binding blood protein (transferrin) to the estimated transmitting ability of AI sires (17, 18). The transferrin is controlled by one genetic locus with multiple alleles. The transferrin types were supplied by the University of California; the sire evaluation information was supplied by the BARC Animal Improvement Programs Laboratory. The analysis showed that the high and low genotypes in Holsteins differed by about 32 kg in transmitting ability for milk. However, differences among genotypes for the other breeds were smaller, and the rank order of genotypes differed from that in Holsteins. This work suggests that typing for transferrin is not worthwhile solely as an aid to pedigree estimation of

breeding value, but it is worth using if typing is done primarily for parentage verification purposes.

Genotype X Nutrition Interaction

Historically, BARC supervised research at Lewisburg, Tenn., and Logan, Utah. R. D. Plowman had this responsibility when experiments on genotype X nutritional regime interaction projects were designed and carried out at these two research stations. At each place, experiments were conducted in which the diets compared were all-forage and normal forage-grain ration. Also, at Logan a second experiment was conducted comparing high and low grain allocations. In all three experiments, sire of cow was used as the genetic control factor. Results (19, 58) were comparable in showing relatively few changes in rank of sires when progeny performances on the different diets were compared. This suggested that errors in sire evaluation due to differences in nutritional regimes are likely to be very small when evaluated throughout the population as a whole. Preliminary results at Logan suggested that sire differences are larger on the more favorable nutritional regimes.

Selection

Subsequently at Lewisburg a selection experiment was undertaken with Jerseys, in which a milk selection and an unselected control line were formed. A preliminary summary (57) showed that the selection line exceeded the control line by 464 kg of milk, which is about 25 percent above expectation. Correlated changes in reproduction, health, and cow care traits have not yet been assessed.

Inheritance of Blood Cholesterol Content

As part of the close cooperation between BARC and the Logan station, R. H. Miller assisted in a study of the relation of inheritance to variation in blood serum cholesterol of dairy cattle (1). There has been much discussion of the effect of various factors, especially diet, in affecting the cholesterol level in humans because of the association of cholesterol and cardiovascular disease. Repeated samples of blood were drawn from 119 lactating cows and 188 immature heifers. Heritability estimates were 0.50 for lactating cows but only 0.19 for heifers. Cholesterol levels were much higher (172.8 vs. 121.4 mg/100 ml) in cows than in heifers. During lactation, serum cholesterol content gradually increased. Interestingly, diets differing radically with respect to satisfying the cows' energy requirements did not significantly affect the blood cholesterol level.

Effect of Weather Conditions on Cow Performance

BARC data were used in a cooperative study at Cornell University on how variations in temperature, wind velocity, and relative humidity affect cow performance during summer weather (30). Pooled over stages of lactation, 9 percent of the variation in milk yield, 13 percent in fat yield, 5 percent in feed consumption, and 65 percent in rectal temperature were attributable to

weather variables. A lag time of 2-3 days in the impact of weather changes on milk yield was found. Performance of cows in midlactation was most affected by weather conditions.

PL 480 Research Involvement

Personnel at BARC have been involved in several projects in other countries, including India, Pakistan, Poland, and Egypt. Projects are in process in Egypt on sire environment interaction, in Poland on evaluation of national Friesian strains, and in Pakistan on creation of a synthetic strain by crossbreeding. In addition, a project with A. Zarnecki at Krakow, Poland, is in the final approval stages. It will be a study of genetic variation in reproductive performance with a dual-purpose cattle breed.

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